REPORT OF COOPERATIVE RESEARCH ON INSECT CONTROL IN FARM STORED GRAIN

No. 18. Period--October 1 to December 31, 1945

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The material in this report consists largely of unpublished data ~~and should be kept confidential.~~ It is made available in its present form for the convenience of the various State and Federal Agencies concerned with the preservation of stored grain from insect damage.

WHEAT STORAGE

Studies on the Fluctuations of Insect Populations in Wheat Stored under Different Systems of Management*

The study on the fluctuations of insect populations in wheat stored in Ever-Normal granary-type bins has been continued during the quarter. Five-probe samples were taken at bi-weekly or monthly intervals from the upper southwest quadrant of 40 bins in the Management Series, and the number of insects by species was determined for each sample. A summary of the data obtained during the current year is given in table 1. The lesser grain borer (Rhyzopertha dominica F.) and the rice weevil (Sitophilus oryza L.) are classed as "weevils" and all other species are combined as "bran bugs".

It may be noted from table 1 that fumigation in August failed to give protection in bins of 1000 bushels capacity, but in 2740-bushel bins this practice was effective.

The comparative abundance of the different species at various times during the current year is given in table 2. The percentages of the various species were calculated from the numbers observed in the periodic samplings of the bins in the Management Series. It may be noted from table 2 that eleven species of stored grain insects were taken during the year, but that five of them comprised about 99 per cent of the total number of insects recorded.

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* -- Reported by H. H. Walkden, U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine in Cooperation with the Bureau of Plant Industry, Soils, and Engineering.

Table 1.--Summary of the insect populations in the upper southwest quadrant of steel and wood bins, Hutchinson, Kansas, 1945.

Grain storage practice	Average number of insects per 1000-grams												
	Feb. 9	Apr. 1	June 1	July 1	July 15	Aug. 1	Aug. 15	Sept. 1	Sept. 15	Oct. 6	Oct. 20	Nov. 3	Dec. 1
1000-bushel steel bins													
No treatment:													
9.3% moisture	0	0	0.2	0	0	0.6	1.2	1.6	3.4	3.8	2.6	4.0	1.8
	0.4"	0	1.0	0.2	1.0	3.0	2.6	3.4	0.4	4.4	1.6	0.6	0.4
11-11.5% moisture	2.4	0	0.2	0.2	1.2	4.0	18.6	13.6	20.8	45.8	31.8	20.4	45.2
	9.4	8.4	11.4	3.8	9.5	38.8	73.6	67.0	65.9	119.0	111.4	135.0	146.6
White walls and roof	0	0	0	0.2	0	0	0.6	0.8	1.0	2.8	4.0	1.6	2.8
	3.0	0.8	3.5	1.0	1.8	4.8	8.8	10.6	5.8	19.6	5.2	4.2	13.0
Fumigation in August	0.2	0	0.1	0	0.9	2.6	4.9 F	1.3	4.5	10.4	24.0 (1)	2.3	31.8 (1)
	1.5	0.1	3.4	1.9	7.9	9.9	20.3 F	2.0	0.7	7.6	9.3 F	1.4	40.9 F
Fumigation in September	0.2	0	0	0	0.2	1.4	3.8	8.8	21.3 F	0.2	0.6	2.8	2.8
	0.4	0.4	2.4	1.0	1.6	6.6	14.8	29.2	20.2 F	2.0	0.6	1.4	1.4
Fumigation in August and	0	0	0	0.1	0	0.5	0.7 F	0	0	0.3 F	0	0	0
	0.1	0.1	0.2	0.1	2.2	1.5	4.6 F	0.2	0.7	0.8 F	0	0	0
Turn, clean and fumigate	0	0	0.8	0	2.4	2.0	1.6	6.4 T	13.6 F	0	0	0	0
in September	0	0.4	0	0	1.6	2.8	0.4	1.6 T	0.8 F	0	0	0	0

Footnote (1) Dangerous insect populations developed in these bins, necessitating an additional fumigation.

(continued)

Table 1, continued

Grain storage practice	Average number of insects per 1000-grams: Feb. 9	Apr. 1	June 1	July 1	July 15	Aug. 1	Aug. 15	Sept. 1	Sept. 15	Oct. 6	Oct. 20	Nov. 3	Dec. 1
2740-bushel steel bins													
No treatment:													
White walls and roof	0	0	0	0	0	0	0.1	0	0.9	1.7	1.2	0.5	0.1
	0.7	1.7	1.4	0.1	1.1	4.2	6.8	9.8	11.4	23.6	15.0	7.7	11.7
Painted white and grouped for shading	0	0	0	0	0	0	0	0.4	0.3	0.3	0.8	0.1	0.1
	1.2	1.2	0.5	0.6	0.5	1.6	2.1	2.1	2.6	2.6	2.9	2.0	1.2
Fumigation in August	0.05	0	0	0	0	0.5	0.8	0.2	0.2	0.7	1.1	0.8	0.9
	2.3	1.5	1.1	0.7	1.0	1.9	2.8[F]	0.7	0.3	0.3	0.4	0.3	0.2
Fumigation in September	0	0	0	0	0	0.6	0.6	2.1	5.2	0.1	0.4	0.3	0.5
	0.4	1.3	1.2	0.5	0.2	2.8	3.3	7.1	6.4[F]	0.2	0.2	0.1	0.1
Fumigation in August and October	0	0	0	0	0	0.5	1.7	0	0	0.2	0	0	0
	0	0	0	0	0.06	0.9	2.4[F]	0.1	0	0.1[F]	0	0	0
Turn, clean and fumigate in September	0	0	0	0	0	0.2	0.7	2.7	5.5	0	0	0	0
	1.1	0.5	1.5	4.9	6.7	8.2	13.4	14.8[T]	3.8[F]	0	0.1	0	0.5
1500-bushel wood bins													
White walls and roof	0	0	0	0	0	0	0	0.2	0	0	0	0	Terminated
	23.6	2.4	5.2	2.0	2.0	14.8	30.2	27.2	39.4[F]	2.0	4.8	4.4	
White walls	0	0	0	0	0	0	0.8	1.6	1.8	0	0	0	Terminated
	2.8	0.8	1.6	0.6	1.8	10.0	24.8	22.8	30.8[F]	3.6	6.0	1.6	
Red walls	0	0	0	0	0	0.2	1.4	4.4	10.0	0	1.6	0	Terminated
	3.6	1.2	3.2	2.6	9.8	54.0	166.0	132.0	206.2[F]	25.6	40.0[F]	2.8	

Legend: ' = Weevils: includes lesser grain borer and rice weevil.
" = Bran bugs: all species except the weevils.
F = Grain fumigated.
T = Grain turned and cleaned.

Table 2.--Comparative abundance of the species of stored grain insects found in the bins in the management series, Hutchinson, Kansas, 1945.

Date 1945	Flat grain beetle *Laemophloeus minutus* Oliv.	Lesser grain borer *Rhyzopertha dominica* F.	Saw-toothed grain beetle *Oryzaephilus surinamensis* L.	Long-headed flour beetle *Latheticus oryzae* Waterh.	Red flour beetle *Tribolium castaneum* Hbst.	Rice weevil *Sitophilus oryza* L.	Dermestids	Hairy fungus beetle *Typhaea stercorea* L.	Indian meal moth *Plodia interpunctella* Hbn.	Cadelle *Tenebroides mauritanicus* L.	Foreign grain beetle *Ahasverus advena* Waltl.
	Per cent of each species										
Feb. 9	72.3	7.0	12.6	6.8	1.4	0	0	0	0	0	0
Apr. 1	85.7	0	13.4	0	0	0	0	0	0.9	0	0
June 1	61.3	1.0	37.2	0.5	0	0	0	0	0	0	0
July 1	50.2	0.9	43.4	2.7	0	0.9	1.8	0	0	0	0
July 15	40.7	8.0	50.5	0	0.4	0	0.2	0.2	0	0.2	0
Aug. 1	47.2	10.4	22.7	7.1	1.7	0	0.3	0.3	0.3	0.1	0
Aug. 15	51.8	12.4	25.6	8.1	1.5	0.2	0.2	0.1	0.1	0	0
Sept. 1	44.8	13.8	21.8	17.7	1.3	0.1	0.1	0.2	0.2	0.1	0
Sept. 15	33.2	24.3	28.9	12.0	1.5	0.1	0.1	0.1	0	0	0
Oct. 6	42.1	25.1	8.2	19.8	3.4	0.9	0.4	0.1	0	0	0.1
Oct. 20	32.0	32.4	5.3	12.8	15.6	1.4	0.3	0.1	0.1	0	0
Nov. 3	29.4	18.0	2.3	15.1	34.5	0.4	0.3	0.1	0	0	0
Dec. 1	17.9	30.5	2.8	23.2	24.6	0.6	0.2	0.1	0	0.1	0
Total insects observed	9642	5052	4058	3472	2308	108	57	27	17	4	2

The condition of the wheat in the Management Series, as the bins entered the winter is given in the following tabulation:

Management Practice	Number of insects per 1000-gram sample, Dec. 1, 1945 Weevils	Bran bugs
1000-bushel bins		
1. Fumigation in August and October	0	0
2. Turn, clean, and fumigate in September	0	0
3. No treatment, 9.3% moisture content	1.8	0.4
4. Fumigate in September	2.8	1.4
5. Walls and roofs painted white	2.8	13.0
6. Fumigation in August	31.8	40.9
7. No treatment, 11.5% moisture content	45.2	146.6
2740-bushel bins		
1. Fumigation in August and October	0	0
2. Turn, clean, and fumigate in September	0	0.5
3. Painted white and grouped for shading	0.1	1.2
4. Walls and roofs painted white	0.1	11.7
5. Fumigation in September	0.5	0.1
6. Fumigation in August	0.9	0.2

Most of the wheat in the Management Series has now been under observation through five seasons, and the results leave no doubt that, for purposes of long-time storage, fumigation twice per year, in August and October, is the most efficient method of preventing the development of serious insect infestation. Although the method of turning, cleaning and fumigating annually in September is equal in effectiveness, the added cost of turning and cleaning is not justified.

Fumigation annually in September has the advantage of reducing fumigation expense, but the rapid development of insects during August and early September causes some insect damage in the wheat, particularly along the south wall. Experience has shown that those bins in which small centers of infestation have developed are more subject to subsequent infestation, than those in which the insect population has been kept at a low level continuously.

Painting the walls and roofs white has prevented the development of serious insect populations, but during the current year the numbers of insects approached the danger point.

Study of the Migration of Stored Grain Insects by Means of Bin Ventilator Traps

During the past season bin ventilator traps were employed again to study the rate and kind of insect migration into wheat stored in steel bins. The bins were tightly calked at all roof and wall joints except the ventilators, which were fitted with traps to retain the insects entering in this way. A total of six bins were observed, three with walls and roofs painted white, and three with galvanized walls and roofs. The traps were in operation from July 1 to November 17 when two of the bins were emptied. The remaining traps were kept in operation until December 15, and migration into them continued until the week ending December 7. The catches were examined at approximately weekly intervals throughout the season, and number and species of stored grain insects were recorded. The results are summarized in tables 3 and 4.

For the comparable period July 1 to November 17, during which all of the traps were in operation, a total of 6237 insects were captured, about two-thirds of them in the unpainted galvanized bins. The period of greatest migration occurred during September and October. When this study was begun, it was expected that insect migration into the white bins would be uniformly less than that into the unpainted galvanized bins, due to the lower temperatures prevailing in the former group. As may be seen in table 3, this did not prove to be the case. The total catch in two of the white bins exceeded that in two of the unpainted bins. Since no differences due to the location of the bins or condition of grain were observed, it is concluded that insect migration into the traps was due largely to chance.

The heavy migration of insects which occurred during September and October accounts for the rapid re-infestation of the bins in the "Fumigation in August" series.

A total of ten species of stored grain insects were taken in the traps during the season. These are listed in table 4, together with their distribution in the several traps. As may be noted in table 4, the saw-toothed grain beetle was taken in greatest numbers in both types of bins. This species is not known to fly, hence those entering the traps had to walk up the outside walls and roofs of the bins, and through the ventilator openings. The lesser grain borer was taken in much smaller numbers in the painted bins and observations in past years have shown even greater differences in this respect. It would thus appear that the use of white paint on steel bins is an important factor in reducing the hazard of lesser grain borer infestation in wheat stored for long periods.

Table 3.--Number of insects entering ventilator traps in white and galvanized steel bins, Hutchinson, Kansas, 1945.

Date, 1945	Painted white bins				Unpainted galvanized bins			
	Bin numbers			Total insects	Bin numbers			Total insects
	1-6	1-2	4-8		1-7	4-9	3-8	
July 2-9	1	1	4	6	3	7	0	10
July 9-16	0	0	17	17	10	16	0	26
July 16-23	6	1	16	23	25	25	41	91
July 23-30	6	2	13	21	18	54	46	118
July 30-Aug. 6	2	9	18	29	19	30	51	100
Aug. 6-13	2	3	3	8	32	37	65	134
Aug. 13-20	11	12	14	37	22	38	44	104
Aug. 20-27	1	6	23	30	33	38	41	112
Aug. 27-Sept. 3	6	13	24	43	25	82	125	232
Sept. 3-10	9	25	37	71	34	65	215	314
Sept. 10-22	1	51	49	101	7	13	199	219
Sept. 22-29	3	96	114	213	14	41	703	758
Sept. 29-Oct. 6	1	30	170	201	11	67	495	573
Oct. 6-13	6	132	317	455	17	87	339	443
Oct. 13-20	1	121	235	357	37	85	297	419
Oct. 20-27	1	45	43	89	4	29	50	83
Oct. 27-Nov. 3	0	66	79	145	8	14	350	372
Nov. 3-10	1	31	21	53	12	12	45	69
Nov. 10-17	0	74	41	115	0	31	15	46
Totals	58	718	1238	2014	331	771	3121	4223
Per cent of total	0.9	11.5	19.8	32.3	5.3	12.4	50.0	67.7

Table 4.--Comparative abundance of the species of stored grain insects taken in ventilator traps in white and galvanized bins, Hutchinson, Kansas, 1945.

Species	Total catch								
	White bins				Galvanized bins				Total all bins
	Bin numbers			Total	Bin numbers			Total	
	1-6	1-2	4-8		1-7	4-9	3-8		
Saw-toothed grain beetle	6	5	1021	1032	73	300	2688	3061	4093
Flat grain beetle	20	82	110	192	140	215	228	583	775
Red flour beetle	4	559	4	567	2	10	16	28	595
Lesser grain borer	16	18	76	110	90	209	163	462	572
Dermestids	1	1	10	12	7	27	21	55	67
Hairy fungus beetle	7	0	12	19	12	5	3	20	39
Rice weevil	0	35	3	38	0	0	0	0	38
Indian meal moth	0	36	0	36	0	0	0	0	36
Foreign grain beetle	3	1	0	4	6	0	2	8	12
Long-headed flour beetle	1	1	2	4	1	5	0	6	10
Totals	58	718	1238	2014	331	771	3121	4223	6237

Control of Insects in Farm Stored Grain by Means of Interior Wall Treatments

As indicated in previous reports, the walls of 67 wooden farm granaries have been treated with various materials to control stored grain insects, especially those species which bore into the walls. The bins were sampled shortly after they were filled with the 1945 crop, and again during October. Observations were made on the degree of insect infestation, the amount of insect damage, moisture content of the grain, and any other points pertaining to the effectiveness of the various treatments. Samples were taken in the surface grain, the center of the bin, and next to the walls in order to detect any differences in insect infestation and damage in various portions of the grain. A summary of these data is given in table 5. The figures for moisture content and insect infestation are the means of all the sample values from the bins. After observing the enormous numbers of insects which were killed in the bins immediately after treatment with DDT, it was surprising to find that some of them developed fairly large insect populations during the season. It is realized that the various bins are not directly comparable, due to the wide variations in original infestations. However, as may be noted in table 5, the average infestation in the treated bins was well below the average for the untreated checks.

In addition to the moisture and infestation data, observations were made on the amount of damage caused by insects during the 4-month period of storage from the time of filling the bins in July to the end of October. One-ounce samples were cut from the 1-quart infestation samples and examined for insect damage. The per cent damage was calculated on a weight basis. The results in 9 bins receiving wall treatments and in one untreated check bin are given in table 6. It may be seen from the table that during the first four months of storage, some insect damage to the wheat occurred in all of the bins. In general, the greatest injury was noted in the surface grain. The damage consisted almost entirely of the consumption of the germ.

The DDT oil emulsion and the water suspension powder were supplied by the Grasselli Chemicals Department, E. I. duPont de Nemours & Company.

The Thanite and Thanisol were supplied by the Hercules Powder Company. Thanisol is a water miscible formula of Thanite.

Table 5.--Results of interior wall treatments for control of insects in farm stored grain, Reno and Stafford Counties, Kansas, 1945.

Cooperator	Bin	Kind of grain	Number of bushels	July sampling: Moisture per cent	July sampling: No. of insects per M. Grams	October sampling: Moisture per cent	October sampling: No. of insects per M. grams
DDT, 5% solution in deobase oil							
R. Dade	SW	Oats	250	12.4	1.6	12.4	1.3
Bacon	SW	Barley	400	12.2	2.7	12.6	2.7
R. Dada	NE	Wheat	600	11.8	0.1	11.6	11.2
E. Swanson	E	Wheat	1000	13.5	0.2	13.3	11.7
Oldenettel	W	Wheat	200	12.2	2.0	12.2	32.0
Average, 5 bins					1.3		11.8
DDT, 3% solution in deobase oil							
Snodgrass	SE	Wheat	850	13.1	0	12.3	2.7
Snodgrass	SW	Wheat	850	12.7	0	12.2	5.2
P. Dade	W	Wheat	250	11.6	1.1	11.4	8.0
Coberly	NE	Wheat	550	12.5	0	13.3	9.0
R. Dade	NC	Wheat	600	11.4	0.4	11.2	15.5
Average, 5 bins					0.3		8.1
DDT, 1% solution in deobase oil							
Wallsten	W	Wheat	550	12.9	0.2	13.4	3.3
R. Dade	NW	Wheat	600	13.2	0.6	12.2	13.4
Average, 2 bins					0.4		8.4
DDT, 0.5% solution in deobase oil							
Gilmore	EC	Wheat	200	12.1	0	12.3	0.7
DDT, 1% in oil emulsion							
Gilmore	E	Wheat	600	12.2	0.3	12.2	0.7
Welte	BC	Wheat	350	11.5	1.3	10.6	16.0
Average, 2 bins					0.8		8.4
DDT, 0.5% in oil emulsion							
Gilmore	WC	Wheat	250	12.0	0	11.8	0.7

(continued)

Table 5 (continued)

Cooperator	Bin	Kind of grain	Number of bushels	July sampling Moisture Per cent	July sampling No. of insects per M. grams	October sampling Moisture Per cent	October sampling No. of insects per M. grams
DDT, 5% in water suspension							
Rayl	NE	Wheat	600	12.6	0	13.2	2.0
Danford	W	Oats	475	16.0	1.8	14.3	20.7
Goodenough	N	Wheat	1050	14.0	0.3	14.2	24.3
Average, 3 bins					1.1		15.7
DDT, 3% in water suspension							
Danford	WC	Wheat	480	12.6	0	12.8	6.3
Goodenough	SW	Wheat	500	12.9	0.3	12.8	13.7
Schulz	E	Wheat	1100	12.7	0.9	12.6	18.3
Average, 3 bins					0.6		12.8
DDT, 1% in water suspension							
Schulz	W	Wheat	575	13.4	6.0	12.6	2.0
Keller	SW	Wheat	400	12.2	0	12.7	2.3
Keller	NW	Wheat	800	13.2	1.3	13.3	3.7
Rayl	SE	Wheat	625	13.3	0.7	12.5	4.7
Goodenough	SE	Wheat	500	12.9	0.4	12.7	5.1
Danford	C	Wheat	480	12.1	0.2	12.0	6.8
Average, 6 bins					1.4		4.1
DDT, 0.5% in water suspension							
Gilmore	W	Wheat	800	12.0	1.1	12.4	0.7
Wallsten	S	Wheat	700	12.6	0	12.5	1.3
Peirce	BC	Wheat	1700	12.1	1.7	12.6	2.0
Danford	EC	Wheat	300	12.3	0	12.3	2.8
Average, 4 bins					0.7		1.7
DDT, 3%; Thanite, 5% solution in deobase oil							
Pennington	SE	Wheat	675	13.7	0	13.1	4.0
Wallsten	C	Wheat	700	11.9	0.1	12.3	8.0
Average, 2 bins					0.1		6.0
Thanite, 10% in deobase oil							
Snodgrass	NW	Wheat	850	12.8	0.3	12.9	8.8
E. Swanson	EBC	Wheat	1600	12.3	2.8	12.3	13.0
Snodgrass	NE	Wheat	850	12.3	1.0	12.3	23.2
Average, 3 bins					1.4		15.0

(continued)

Table 5 (continued)

Cooperator	Bin	Kind of grain	Number of bushels	July sampling Moisture Per cent	July sampling No. of insects per M. grams	October sampling Moisture Per cent	October sampling No. of insects per M. grams
Thanisol, 10% in water emulsion							
Wallsten	E	Wheat	775	12.7	0	12.2	10.0
Whitewash, 2 coats							
Bacon	NW	Wheat	200	14.6	0.8	14.5	6.0
Goodenough	S	Wheat	460	--	--	12.2	9.7
Average, 2 bins					--		7.9
White lead paint, 2 coats							
Bacon	NE	Wheat	200	13.7	10.5	13.6	4.7
Red barn paint, 2 coats							
P. Dade	NE	Wheat	900	12.0	1.3	12.2	18.8
Hodgson	W	Wheat	725	12.7	1.6	12.4	28.7
Average, 2 bins					1.5		23.8
Asphalt paint (trade name "Ebanol")							
P. Dade	SE	Wheat	825	12.2	0.8	13.9	12.0
Creosote (applied by cooperator)							
Keller	SE	Wheat	800	12.9	1.3	11.8	3.0
Keller	NE	Wheat	550	12.1	2.7	11.8	14.0
Average, 2 bins					2.0		8.5
No treatment (check bins)							
G. Swanson	TS	Wheat	1560	--	--	12.5	12.0
Coberly	NW	Oats	600	11.8	2.6	12.1	17.0
E. Swanson	WBC	Wheat	1000	11.1	10.0	11.1	26.8
Dixon	E	Oats	100	--	--	10.9	80.0
Dixon	N	Wheat	100	--	--	12.8	83.0
Dixon	S	Wheat	700	--	--	15.8	106.0
Dixon	EC	Wheat	500	--	--	12.6	244.7
Average, 7 bins					--		81.4

Table 6.--Amount of insect damage to wheat stored in wooden farm granaries with different wall treatments, Reno County, Kansas, 1945.

Cooperator	Bin	Amount of insect damage, per cent by weight: Location of sample: Center	Surface	North Wall	East Wall	South Wall	West Wall
DDT, 1% solution in deobase oil							
R. Dade	NW	1.25	5.25	--	2.83	--	--
DDT, 3% solution in deobase oil							
R. Dade	NC	0.55	--	--	--	--	1.33
DDT, 5% solution in deobase oil							
R. Dade	NE	0.66	2.74	--	--	--	0.87
Oldenettel	W	3.08	2.00	1.84	1.76	2.76	3.15
DDT, 1% oil emulsion							
Welte	BC	1.95	3.25	--	--	1.57	--
DDT, 1% water suspension							
Keller	SW	0.42	1.25	0.42	0.42	0.28	0.49
Goodenough	SE	1.21	1.66	1.46	--	0.69	0.42
DDT, 3% water suspension							
Goodenough	SW	1.86	3.89	0.93	0.28	0.83	--
DDT, 5% water suspension							
Goodenough	N	0.28	5.06	0.97	--	0.35	--
No treatment (check bin)							
Swanson	WBC	0.14	--	3.07	3.44	--	3.87

Experimental Fumigation of Wheat and Other Stored Grains

During the past quarter, 30 bins, totalling approximately 48,000 bushels of grain, were fumigated experimentally. These fumigations were concerned with the evaluation of ethylene dibromide as a surface toxicant in the control of surface infestations in stored grain. Carbon tetrachloride and the 3:1 mixture of ethylene dichloride - carbon tetrachloride were used as controls. For this work, bins were chosen, as far as possible, in which heavy surface infestations were present. The results are summarized in table 7.

In wheat, all of the mixtures containing 5 per cent of ethylene dibromide gave good surface kills. The overall kills were satisfactory for all of the mixtures with one exception; namely, the material containing ethylene dibromide, 5%; 3:1 mixture of ethylene dichloride - carbon tetrachloride, 95%.

In sorghum, poor results were obtained at twice the dosage used in wheat. This is in line with past experience with grain sorghum. Recently, several bins of grain sorghum have been put in storage at the Hutchinson Bin Site, and it is hoped that fumigation dosages can be established during the coming summer season.

Table 7.--Summary of results of fumigation of grain stored in steel and wooden bins, Hutchinson, Kansas, October-December, 1945.

Note: All bins contained stored wheat except as indicated in the table.

Bin No.	Capy. (bu.)	Date treated	Dosage M/bu. (gals.)	Test probes	Per cent Mortality: Surface Capsules	Per cent Mortality: Overall kill	Per cent Mortality: Natural Population
I - STEEL BINS							
Carbon tetrachloride							
3-13	1000	10/1	2	99	97	99	83
4-12	1000	10/1	2	98	97	98	97
11-10	2740	10/1	2	100	100	100	99
7-3	2740	10/1	2	--	--	--	88
7-4	2740	10/1	2	--	--	--	89
11-11	2740	10/1	2	--	--	--	100
Ethylene dichloride, 75%; Carbon tetrachloride, 25%							
4-14	1000	10/1	4	81	100	86	100
6-9	2740	10/1	4	95	100	96	100
6-10	2740	10/1	4	--	--	--	100
Ethylene dibromide, 5%; Carbon tetrachloride, 95%							
1-16	1000	10/2	2	99	100	99	98
7-10	2740	10/3	2	99	100	99	90
1/2-7*	1000	10/2	3	89	99	93	92
Ethylene dibromide, 10%; Carbon tetrachloride, 90%							
2-16	1000	10/2	2	100	98	99	99
Ethylene dibromide, 5%; 3:1 mixture Ethylene dichloride - Carbon tetrachloride, 95%							
5-8	2740	10/3	2	46	100	63	93
7-2	2740	10/3	3	97	100	98	100
1/2-8*	1000	10/2	3	58	100	74	95
Ethylene dibromide, 5%; Ethylene dichloride, 35%; Carbon tetrachloride, 60%							
3-15	1000	10/8	1	62	67	64	30
4-13	1000	10/8	2	92	100	95	85
4-16	1000	10/8	2	96	100	98	87
10-7	2000	10/2	2	99	100	99	96
10-8	2000	10/2	2	99	100	99	100

* - These bins with perforated steel floors on 2" x 4" joist.

(continued)

Table 7 (continued)

Bin No.	Capy. (bu.)	Date treated	Dosage M/bu. (gals.)	Test probes	Per cent Mortality Surface Capsules	Overall kill	Natural Population
Grain sorghum in mechanically ventilated bins with perforated floors.							
Carbon tetrachloride							
4-1**	1000	10/8	4	41	91	64	27
Ethylene dibromide, 5%; Carbon tetrachloride, 95%							
4-2**	1000	10/8	4	33	97	56	43
Ethylene dibromide, 5%; Ethylene dichloride, 35%; Carbon tetrachloride, 60%							
4-3**	1000	10/8	4	47	81	58	60
II - WOODEN BINS							
Carbon tetrachloride							
13-5	1500	10/3	3	99	99	99	100
Ethylene dichloride, 75%; Carbon tetrachloride, 25%							
13-6	1500	10/3	3	67	100	80	78
13-10	1500	10/27	4	--	--	--	93
Ethylene dibromide, 5%; Carbon tetrachloride, 95%							
13-9	1500	10/3	3	99	100	99	95
Ethylene dibromide, 5%; 3:1 mixture Ethylene dichloride - Carbon tetrachloride, 95%							
13-10	1500	10/3	3	50	99	89	69
Ethylene dibromide, 5%; Ethylene dichloride, 35%; Carbon tetrachloride, 60%							
13-11	1500	10/3	3	98	100	99	99

** - These bins contained 500 bushels of sorghum.

Effect of Chemical Dusts on the Prevention of Infestation of Bagged Wheat*

To test the effect of various chemical dusts, applied directly to wheat, upon the prevention of infestation, lots of 500 grams of wheat were exposed to heavy populations of the various common grain insects. Wheat with a moisture content of 14% was treated with the various chemical dusts, as listed in table 8, bagged and exposed to infestation in a metal tank. The bottom of the tank was covered with a layer of wheat heavily infested with a variety of stored grain insects. After an exposure period of three months, the wheat was examined and the number of live and dead insects counted. The results of this examination appear in table 8. It will be noted that none of the treatments prevented insects from getting into the bags of wheat, but in most cases the insects apparently died soon after coming in contact with the treated wheat. The fact that the check lots showed no heavier infestation than most of the treatments indicates that the rapid drying out of the wheat greatly affected the results. Since these test lots were kept in the attic where the humidity of the air has been quite low, it is quite likely that the wheat had dried out to a rather low moisture content.

All treatments are still being held for future observations.

Three treatments were included in this series in which only the bags were treated. The bags were dipped into the designated solution and allowed to dry before filling with wheat. In these treatments some insects were able to penetrate the bags but died after getting into the wheat.

No reproduction and practically no damage to the wheat was noted in any of the treatments.

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* - Reported by R. T. Cotton and J. C. Frankenfeld, Bureau of Entomology and Plant Quarantine.

Table 8.--Effect of chemical dusts on the prevention of infestation of bagged wheat.

Treatment	Dosage Percent by weight	Insects found after 3 months*	
		Alive	Dead
Bag treated with DDT sol.	5.0	0	1 sawtoothed grain beetle 1 rice weevil
Do.	5.0	0	1 cadelle larva 4 sawtoothed grain beetle
Bag treated with DDT sol.	1.0	1 cadelle larva 1 sawtoothed grain beetle	2 cadelle larvae 6 sawtoothed grain beetle
Do.	1.0	1 cadelle larva 1 sawtoothed grain beetle	2 cadelle larvae 9 sawtoothed grain beetle
Bag treated with methoxy analog of DDT	5.0	4 sawtoothed grain beetle	2 cadelle larvae 13 sawtoothed grain beetle 2 rice weevil
Do.	5.0	0	4 cadelle larvae 1 rice weevil
Do.	1.0	2 Indian meal moth larvae	0
Do.	1.0	1 cadelle larva 1 sawtoothed grain beetle	4 cadelle larvae 6 sawtoothed grain beetle
Grain treated: MgO + 3% DDT	0.05	1 cadelle larva	6 cadelle larvae 2 cadelle 1 rice weevil
Do.	0.05	1 cadelle larva	2 cadelle larvae 2 rice weevil
Grain treated: MgO + 5% DDT	0.05	3 sawtoothed grain beetle	24 sawtoothed grain beetle 4 rice weevil
Do.	0.05	0	4 sawtoothed grain beetle 1 rice weevil
Grain treated: Ceresan	0.05	1 sawtoothed grain beetle	1 flour beetle Numerous sawtoothed grain beetle larvae
Do.	0.05	0	2 rice weevil

* - Except where indicated, insects listed are adults.

Table 8 (continued)

Treatment	Dosage Percent by weight	Insects found after 3 months*	
		Alive	Dead
Grain treated: MgO + 10% P-nitro chloro-benzene	0.1	5 cadelle	3 cadelle larvae
Do.	0.1	1 rice weevil	0
Grain treated: Ceresan + 1% DDT	0.05	0	3 cadelle larvae
Do.	0.05	0	4 cadelle larvae 2 sawtoothed grain beetle 2 rice weevil
Do.	0.005	0	5 sawtoothed grain beetle 2 rice weevil
Do.	0.005	0	4 cadelle larvae 6 sawtoothed grain beetle
Grain treated: Barbak	0.2	1 cadelle	2 sawtoothed grain beetle
Do.	0.2	0	3 cadelle larvae 1 sawtoothed grain beetle
Grain treated: Barbak + 1% DDT	0.05	0	6 cadelle larvae 8 sawtoothed grain beetle 1 rice weevil
Do.	0.05	0	1 cadelle larvae 3 sawtoothed grain beetle
Grain treated: 2% benzene hexachloride	0.05	0	6 sawtoothed grain beetle 5 rice weevil
Do.	0.05	1 sawtoothed grain beetle	3 cadelle larvae 12 sawtoothed grain beetle 1 flour beetle
Check: No treatment		2 sawtoothed grain beetle	3 sawtoothed grain beetle 3 Indian meal moth larvae
Do.		1 cadelle larva 1 sawtoothed grain beetle 2 Indian meal moth larvae	10 Indian meal moth larvae

Effect of Temperature, Moisture and Dockage on the Survival and Reproduction of the Red Flour Beetle*

In Report No. 17 partial results of a series of tests conducted with the red flour beetle at 90° F. were discussed. This series was completed during the past quarter, and results on the percentage of survival of adults are summarized in table 9. In wheat with a 9% moisture content all adults were dead in the clean wheat lot after two weeks, and after eleven weeks in the lot containing 0.5% dockage. In the lots containing 1, 2, 4, and 8% dockage, there was no difference in the percentage of survival attributable to presence of increased amounts of dockage, until the 19th week. At this time the percentage of survival in the 1% dockage lot had dropped to 5%, while the 2, 4, and 8% lots had a survival of 30, 20, and 35% respectively.

In the series containing 12% moisture wheat, the low percentage of survival in practically all lots was finally attributed to the fact that the whole wheat flour which was used as dockage, had had some sulfuric acid solution spilled on it, which was not noticed at the time that the series was set up. In order to get the flour adjusted to the proper moisture content it is held in a desiccator over a solution of sulfuric acid whose density is adjusted to furnish the desired relative humidity.

In the 15% moisture series there was little difference in the percentage of survival in the various dockage lots until after the 13th week. Following this length of time there is a slight difference in favor of the lots containing increased amounts of dockage.

This series of tests emphasizes results of other tests previously conducted, in that dockage has little significance in the percentage of survival in a given moisture range. However, some dockage must be present in the drier wheat, which is too hard for the adults to feed upon. In 15% moisture wheat, the adults are able to survive in clean wheat almost as well as in wheat with dockage.

From the standpoint of reproduction the amount of dockage is very important. Table 10 shows the weekly recovery of pupae for the series of tests conducted at 90° F. At this temperature the first pupae were recovered at the end of the third week. Fairly large numbers of pupae were recovered during the 3rd, 4th, and 5th weeks. In the 9% moisture series, recovery of pupae was complete after the 7th week. In the 12 and 15% series by far the majority of pupae were recovered during the 3rd, 4th, and 5th weeks after which the numbers recovered were very irregular, although some pupae were recovered until the series was discontinued. In general however, the number of pupae recovered increases as the moisture content of the wheat increases and as the amount of dockage in the wheat increases.

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* - Reported by R. T. Cotton and J. C. Frankenfeld.

Table 9.--Percentage of survival of the red flour beetle in 9, 12, and 15% moisture wheat, with varying amounts of dockage at 90° F. (Continued from July-Sept. 1945 report.)

Moisture content of wheat and food medid	Percentage survival after								
	11th week	12th week	13th week	14th week	15th week	16th week	17th week	18th week	19th week
9% Wheat									
Clean wheat	0								
Same + 0.5% Dockage	0								
Same + 1.0% "	60	60	55	45	40	30	25	20	5
Same + 2.0% "	80	75	65	60	55	40	30	30	30
Same + 4.0% "	60	50	45	35	35	30	25	25	20
Same + 8.0% "	75	65	65	60	55	55	50	35	25
12% Wheat									
Clean wheat	20	20	15	10	10	5	5	5	5
Same + 0.5% Dockage	35	30	25	25	15	15	10	10	10
Same + 1.0% "	60	55	35	25	25	25	15	10	10
Same + 2.0% "	35	35	35	35	35	35	35	30	30
Same + 4.0% "	0								
Same + 8.0% "	5	5	5	0					
15% Wheat									
Clean wheat	90	80	80	70	65	55	50	30	20
Same + 0.5% Dockage	90	85	85	85	75	55	50	40	40
Same + 1.0% "	95	90	80	75	60	55	45	35	25
Same + 2.0% "	80	80	80	75	65	60	60	40	40
Same + 4.0% "	90	90	90	90	90	90	90	70	55
Same + 8.0% "	95	90	90	85	85	80	75	75	75

Table 10.--Weekly recovery of T. castaneum pupae from 9, 12, and 15% moisture wheat with varying amounts of dockage at 90° F.

Moisture content of wheat and food media	Number of pupae recovered after																	Total
	3rd Week	4th Week	5th Week	6th Week	7th Week	8th Week	9th Week	10th Week	11th Week	12th Week	13th Week	14th Week	15th Week	16th Week	17th Week	18th Week	19th Week	
9% Wheat																		
Clean wheat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Same + 0.5% Dock.	0	11	11	4	7	2	0	0	0	0	0	0	0	0	0	0	0	35
Same + 1.0% "	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Same + 2.0% "	0	13	13	3	1	1	1	0	0	1	0	0	1	0	2	0	1	37
Same + 4.0% "	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Same + 8.0% "	0	19	12	1	1	0	0	0	0	0	0	0	0	0	0	0	0	33
12% Wheat																		
Clean wheat	0	2	6	11	10	2	0	0	0	4	4	9	9	11	2	1	0	71
Same + 0.5% Dock.	6	43	5	0	1	13	12	9	5	3	2	2	2	4	2	1	1	111
Same + 1.0% "	11	67	13	2	0	2	1	0	0	0	0	0	1	0	0	1	1	99
Same + 2.0% "	3	18	54	6	2	0	0	0	0	1	0	0	0	0	0	0	0	104
Same + 4.0% "	1	4	18	26	3	1	0	0	0	0	0	0	0	0	0	0	0	53
Same + 8.0% "	0	9	47	9	0	14	11	4	0	1	0	0	0	0	0	0	0	95
15% Wheat																		
Clean wheat	1	29	26	0	1	0	0	0	1	8	3	1	1	1	0	0	3	75
Same + 0.5% Dock.	5	56	8	0	9	3	4	9	5	5	1	2	2	0	3	2	5	119
Same + 1.0% "	32	61	5	3	10	17	7	8	3	4	2	3	2	0	2	3	2	164
Same + 2.0% "	86	66	5	1	10	37	14	12	20	18	5	5	1	1	1	0	0	282
Same + 4.0% "	119	77	3	0	30	32	8	26	17	7	18	9	2	0	0	0	0	348
Same + 8.0% "	105	104	10	1	41	17	1	31	8	4	9	3	0	0	0	0	0	334

In another series of tests which has been in progress for 16 weeks, a constant temperature of 75° F. was used. The percentage of survival at weekly intervals is summarized in table 11. Here again, except in the 9% moisture series, the amount of dockage present in the wheat has no effect upon the survival of adults. In the clean wheat lot of the 9% moisture series, all adults had died by the end of the 6th week. At the end of the 16th week, there was some significant reduction in survival in the 0.5% and 1.0% dockage lots. In the 12 and 15% moisture series there is no significant difference in survival either as affected by moisture or by dockage.

Reproduction of the red flour beetle, although greatly reduced at a constant temperature of 75° F., follows much the same pattern as was true in our tests at other temperatures. That is, reproduction increases as the moisture content of the grain is increased, and as the amount of dockage is increased. The period of time elapsed from the start of the test until the first pupae are recovered varied considerably at the different moisture levels, and also for the different dockage lots within a given moisture level. Thus, the first pupae were recovered in the 15% moisture wheat after six weeks. In the 12% wheat the first pupae were recovered in 4 and 8% dockage lots after six weeks; in 0.5, 1, and 2% dockage lots after 7 weeks; and not until after 8 weeks in the clean wheat. In the 9% series the first pupae were recovered in the 4 and 8% dockage lots after 8 weeks, and in the 0.5, 1, and 2% lots after 9 weeks. Again, as in all of our previous tests there is a tendency for reproduction to be concentrated over a few weeks, after which it is greatly retarded or ceases entirely.

An effort is being made to determine what factors influence this apparent cessation of reproduction in our tests. Records of other investigators show that this species may lay viable eggs for periods of a year or more. The first of these efforts deals with the changing of the food media. In all of our tests on the effect of temperature, moisture, and dockage, we used the same food throughout the length of a given series. On the assumption that the presence of adults in a given quantity of food may affect their potential rate of reproduction, a series of tests were started in which the food was changed at variable intervals. In one lot the food is changed at weekly intervals, in a second lot the food is changed every four weeks, and in a third lot, the food is left unchanged. The eggs are sifted from the flour from each lot twice a week and counted. Since we experienced similar conditions in our tests with the confused flour beetle, a like series was set up for this species also. Twenty grams of finely ground whole wheat flour are used in each lot, into which 10 unmated females and 10 unmated males were admitted at the start of the test. Erlenmeyer flasks containing the flour and insects are kept at a constant temperature of 75° F. and a relative humidity of 46%.

Table 11.--Percentage of survival of the red flour beetle in 9, 12, and 15% moisture wheat with varying amounts of dockage at 75° F.

Moisture content of wheat and food media	Percentage survival after														
	1 Week	2 Weeks	3 Weeks	4 Weeks	5 Weeks	6 Weeks	7 Weeks	8 Weeks	9 Weeks	10 Weeks	11 Weeks	12 Weeks	13 Weeks	14 Weeks	15 Weeks	16 Weeks
9% Wheat																
Clean wheat	95	90	80	50	25	0										
Same + 0.5% Dockage	100	100	100	100	100	95	90	90	85	85	80	80	80	75	65	45
Same + 1.0% "	85	85	85	80	80	80	80	80	80	80	75	75	70	70	65	65
Same + 2.0% "	100	100	100	100	100	100	100	100	100	100	100	100	95	90	85	85
Same + 4.0% "	100	100	100	100	100	100	100	100	100	100	95	95	95	95	95	95
Same + 8.0% "	100	100	95	95	95	95	95	95	95	95	90	85	85	85	85	85
12% Wheat																
Clean wheat	100	100	100	100	100	95	95	95	95	95	90	85	80	80	80	80
Same + 0.5% Dockage	95	95	95	95	95	95	95	95	95	95	90	90	90	90	90	90
Same + 1.0% "	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95
Same + 2.0% "	100	100	95	95	95	95	95	95	95	95	95	95	95	95	95	95
Same + 4.0% "	100	100	100	95	95	95	85	85	85	85	80	80	80	80	80	80
Same + 8.0% "	100	100	100	100	100	100	95	95	95	95	95	90	90	90	90	90
15% Wheat																
Clean wheat	100	100	95	95	95	95	95	95	95	95	95	95	90	90	90	90
Same + 0.5% Dockage	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Same + 1.0% "	100	100	100	100	100	100	95	95	95	95	95	95	95	95	90	90
Same + 2.0% "	100	100	95	90	90	90	90	90	90	90	90	90	90	90	90	90
Same + 4.0% "	100	100	100	100	95	95	95	95	95	90	90	90	90	90	90	90
Same + 8.0% "	100	100	100	100	100	100	100	100	95	95	95	95	95	95	95	95

Table 12.--Weekly recovery of *T. castaneum* from 9, 12, and 15% moisture wheat with varying amounts of dockage at 75° F.

Moisture content of wheat and food media	Number of pupae recovered after											Total
	6th week	7th week	8th week	9th week	10th week	11th week	12th week	13th week	14th week	15th week	16th week	
9% Wheat												
Clean wheat	0	0	0	0	0	0	0	0	0	0	0	0
Same + 0.5% Dock.	0	0	0	1	1	6	2	0	0	0	0	10
Same + 1.0% "	0	0	0	3	2	3	0	0	1	0	0	8
Same + 2.0% "	0	0	0	4	8	8	3	2	0	0	0	25
Same + 4.0% "	0	0	3	8	13	4	3	0	1	1	3	38
Same + 8.0% "	0	0	4	18	13	5	1	0	1	0	0	42
12% Wheat												
Clean wheat	0	0	3	3	5	2	0	0	2	0	0	15
Same + 0.5% Dock.	0	3	11	10	20	5	4	3	0	3	1	60
Same + 1.0% "	0	4	14	9	3	1	1	1	1	0	1	35
Same + 2.0% "	0	5	21	15	9	1	3	0	5	3	4	56
Same + 4.0% "	2	9	19	18	5	4	0	0	0	1	4	62
Same + 8.0% "	1	18	35	22	6	2	0	1	3	3	0	91
15% Wheat												
Clean wheat	1	4	2	4	6	2	3	1	1	0	0	24
Same + 0.5% Dock.	1	15	18	18	11	0	1	1	1	1	0	67
Same + 1.0% "	15	31	30	11	2	5	1	2	2	2	1	102
Same + 2.0% "	20	44	21	7	1	1	1	1	5	3	8	112
Same + 4.0% "	28	40	32	6	0	0	2	1	2	0	0	111
Same + 8.0% "	16	60	59	15	5	1	1	0	1	0	0	158

Table 13 summarized the number of eggs laid in each of the above lots at weekly intervals. It will be noted that the changing of the food media has a very decided effect upon the total number of eggs laid by both species. Thus, after 12 weeks, T. castaneum adults laid a total of 1,759 eggs when the food was changed at weekly intervals; 1,561 eggs when the food was changed every four weeks; and 783 when the same food was used. Practically the same relationship holds true in case of T. confusum. The adults of this species laid 2,503 eggs when the food was changed at weekly intervals; 2,405 when changed every 4 weeks; and 1,127 eggs when the food was not changed. Over a period of 12 weeks there is no indication of a decrease in the rate of oviposition, but rather the weekly total of eggs laid seems to be on the increase.

Another series of tests conducted at a constant temperature of 65° F. has been in progress for 10 weeks. Table 14 summarizes the weekly percentage of survival in the various moisture and dockage lots. Here again the amount of dockage has apparently little effect on survival except in the dry wheat.

No reproduction has as yet been observed in any of the tests.

Table 13.--Egg laying record of 10 female T. castaneum and 10 female T. confusum over a period of 12 weeks at 75° f. and 46% R.H.

Egg laying period	Number eggs laid by 10 females of					
	T. castaneum			T. confusum		
	Food changed weekly	Food changed every 4 weeks	Food unchanged	Food changed weekly	Food changed every 4 weeks	Food unchanged
1st week	27	77	60	183	188	75
2nd "	19	17	15	172	255	135
3rd "	52	48	21	215	234	140
4th "	157	90	72	247	155	85
5th "	160	232	50	177	144	9
6th "	202	139	65	177	88	29
7th "	128	89	35	178	103	46
8th "	189	214	57	195	197	86
9th "	180	134	58	230	249	117
10th "	195	161	93	254	262	129
11th "	208	138	120	243	241	123
12th "	242	222	137	282	289	153
Total	1759	1561	783	2503	2405	1127
Ave. per female	175.9	156.1	78.3	250.3	240.5	112.7

Table 14.--Percentage of survival of the red flour beetle in 9, 12, and 15% moisture wheat with varying amounts of dockage at 65° F.

Moisture content of wheat and food media	Percentage survival after									
	1 week	2 weeks	3 weeks	4 weeks	5 weeks	6 weeks	7 weeks	8 weeks	9 weeks	10 weeks
9% Wheat										
Clean wheat	100	85	45	25	5	0				
Same + 0.5% Dock.	100	95	80	80	80	75	55	55	50	50
Same + 1.0% "	95	95	90	90	90	90	75	75	75	75
Same + 2.0% "	90	90	85	85	85	85	85	70	70	70
Same + 4.0% "	100	100	95	95	95	95	95	95	90	90
Same + 8.0% "	100	100	100	100	100	100	100	100	100	100
12% Wheat										
Clean wheat	100	95	95	90	85	85	85	85	85	85
Same + 0.5% Dock.	100	95	90	85	75	75	75	75	75	75
Same + 1.0% "	100	95	95	95	95	95	95	95	95	95
Same + 2.0% "	100	100	100	100	95	95	95	90	90	90
Same + 4.0% "	100	100	100	95	90	90	90	85	85	85
Same + 8.0% "	100	100	100	95	95	95	95	90	90	90
15% Wheat										
Clean wheat	100	100	100	95	90	90	90	90	85	85
Same + 0.5% Dock.	100	100	100	100	100	95	95	95	95	95
Same + 1.0% "	100	100	100	95	95	95	95	95	95	95
Same + 2.0% "	100	100	90	90	85	85	80	80	80	80
Same + 4.0% "	100	100	100	90	85	75	75	75	75	75
Same + 8.0% "	100	100	100	100	80	60	60	60	60	60